



Ecologically unequal exchange, recessions, and climate change: A longitudinal study



Xiaorui Huang

Sociology Department, Boston College, 426 McGuinn Hall, 140 Commonwealth Avenue, Chestnut Hill, MA, 02467, United States

ARTICLE INFO

Keywords:

Environmental sociology
Political economy
Climate change
Ecologically unequal exchange
Economic recessions

ABSTRACT

This study investigates how the ecologically unequal exchange of carbon dioxide emissions varies with economic recessions. I propose a country-specific approach to examine (1) the relationship between carbon dioxide emissions in developing countries and the “vertical flow” of exports to the United States; and (2) the variations of the relationship before, during, and after two recent economic recessions in 2001 and 2008. Using data on 69 developing nations between 2000 and 2010, I estimate time-series cross-sectional regression models with two-way fixed effects. Results suggest that the vertical flow of exports to the United States is positively associated with carbon dioxide emissions in developing countries. The magnitude of this relationship increased in 2001, 2009, and 2010, and decreased in 2008, but remained stable in non-recession periods, suggesting that economic recessions in the United States are associated with variations of ecologically unequal exchange. Results highlight the impacts of U.S. recessions on carbon emissions in developing countries through the structure of international trade.

1. Introduction

Global climate change is one of the most serious problems of the 21st century. Responsibility for and vulnerability to climate change are unevenly distributed among countries occupying different positions in the global economy (Intergovernmental Panel on Climate Change, 2014). Nevertheless, the solutions to climate change require an unprecedented level of international cooperation. Understanding how the structural relationships among countries affect climate change and its mitigation is an important step toward solutions. Sociological research on ecologically unequal exchange has established that the structure of international trade is associated with the uneven distribution of environmental harms to the disadvantage of developing countries (e.g., Bunker, 1984; Jorgenson and Clark, 2011). In particular, the “vertical flow” of exports from developing countries to developed countries is a mechanism through which developed countries partially displace carbon dioxide emissions associated with their high levels of consumption to developing countries (Jorgenson, 2011, 2012). The vertical flow of exports also suppresses resource consumption in developing countries to levels below globally sustainable thresholds (e.g., Rice, 2007), which indicates under-consumption and under-development, and thus undermines the capability of these countries to cope with climate change.

Sociologists have yet to investigate if and how economic recessions affect ecologically unequal exchange through the structure of international trade. It is important to fill this gap because increasing evidence suggests that developed countries are in a period of slow growth and frequent recessions (e.g., Gordon, 2012; Piketty, 2014). Economic recessions affect many aspects of societies, including consumption, investment, and international trade (e.g., Petev et al., 2011; Zimmermann, 1997), and thus potentially affect ecologically unequal exchanges between developed countries and developing countries.

E-mail address: xiaorui.huang@bc.edu.

Among developed countries, the United States is the largest importer and the largest emitter of consumption-based carbon dioxide emissions¹ (Davis and Caldeira, 2010; United Nations, 2015), and experienced two recessions in the past two decades. Prior research finds that in the United States the growth rates of carbon emissions² with per unit of increase in GDP during economic expansions are lower than their reduction rates during recessions (Shahiduzzaman and Layton, 2015), while the opposite is observed in cross-national analyses (York, 2012). The mixture of findings could potentially imply that the structure of trade between the United States and other countries becomes more ecologically unequal during recessions, which might facilitate emissions reductions in the United States during recessions but inhibit emissions reductions in its trade partners.

Using a country-specific approach, this study investigates if and how recent economic recessions affect the ecologically unequal exchange of carbon dioxide emissions between developing countries and the United States. I examine (1) the association between per capita carbon dioxide emissions in developing countries and the vertical flow of exports to the United States; and (2) if and how this association changes before, during, and after recent U.S. recessions.

The results suggest that the ecologically unequal exchange of carbon emissions occurs via the vertical flow of exports from developing countries to the United States. In addition, U.S. economic recessions are associated with variations of ecologically unequal exchange: the structure of trade between the United States and developing countries became more ecologically unequal in recession years 2001, 2009, and in post-recession year 2010, but became less unequal in recession year 2008. The variations are likely associated with changes in the amount of carbon emissions displaced from the United States to developing countries. The findings highlight the impacts of U.S. recessions on carbon emissions in developing countries through the structure of international trade, and suggest that such impacts should be considered when assessing the implications of recessions for climate mitigation.

The present study advances and connects areas of sociological research on ecologically unequal exchange, climate change, and economic recessions. I investigate the understudied relationship between economic recessions and ecologically unequal exchange, in a period when economic recessions become an increasingly important feature of the economic pattern of the Global North. I employ a novel approach that allows researchers to incorporate into analyses events like recessions that are both country- and time-specific. I also consider both the transnational and domestic implications of recessions for climate change and climate mitigation in a global context through the framework of ecologically unequal exchange.

This paper begins with an overview of the literature on ecologically unequal exchange. Next, I review empirical studies on the ecologically unequal exchange of carbon dioxide emissions, and explain their implications for climate change and global climate justice. Third, I review the literature on the impacts of economic recessions on climate change, and discuss why it is important to study potential variations of ecologically unequal exchange during recessions. Fourth, I propose a country-specific approach to analyze such variations and explain the reasons to focus on the United States. Fifth, I describe the data and methods used in the analyses. Then I present the results and discuss their implications, before concluding the paper with suggestions for future research.

2. Literature review

2.1. Ecologically unequal exchange

The theory of ecologically unequal exchange extends the classical trade dependence perspective³ to understand the uneven environmental impacts of the structure of international trade. Bunker's (1984) pioneering research on the Brazilian Amazon draws attention to a vertical net flow of energy and materials from a developing country near the bottom of the global trade hierarchy to powerful developed countries that impose an export-oriented extractive economy upon the former. Bunker argues that this disrupts the socioeconomic and environmental conditions in developing countries and inhibits the development of alternative economies.

Building on Bunker's work and other earlier research, Hornborg (1998) argues that although international trade is often considered to be a fair market transaction in neoclassical economics, in such transactions economic value is inversely related to productive potential⁴: raw materials with high productive potential are assigned low prices by the market, and vice versa. The vertical flow of exports with high productive potential (mostly primary and secondary sector outputs) from developing countries to developed countries is under-compensated economically. As a result, developing countries that undertake export-oriented resource extraction and commodity production acquire few economic gains from the exports, even though they bear high environmental costs, often in the forms of increased domestic pollution and resource depletion.

The theory of ecologically unequal exchange posits that the vertical flow of exports is a mechanism of unequal exchange through which more powerful, developed countries externalize a portion of the environmental costs associated with their consumption to less-powerful developing countries; consequently, developed countries are able to maintain both high levels of domestic consumption and good environmental conditions, while developing countries suffer from environmental harms, low levels of human well-being, and overall under-development (Hornborg, 2009; Jorgenson, 2006, 2012; Jorgenson and Clark, 2009; Rice, 2007). The vertical flow of

¹ Consumption-based emissions include emissions embedded in imports but exclude emissions embedded in exports.

² Unless otherwise specified, the terms "carbon dioxide emissions" and "carbon emissions" in this article refer to production-based emissions (also called territorial emissions) that include emissions embedded in exports but exclude emissions embedded in imports.

³ Trade dependence theory posits that less developed countries with high level of trade dependence are vulnerable to world market forces and are likely to be subjected to unfavorable terms of trade imposed by powerful, developed countries (Galtung, 1971). Previous studies show that trade dependence is negatively correlated with a country's GDP per capita and human well-being, and are positively correlated with income inequality (e.g., Kentor and Boswell, 2003).

⁴ Productive potential, also known as *exergy*, refers to the part of energy in certain substances that is available for mechanical work (Hornborg, 1998; Wall, 1986). When raw materials are converted into products, their productive potential decreases and economic value increases (Georgescu-Roegen, 1971).

exports is partially controlled by transnational corporations headquartered in developed countries that outsource polluting economic activities, including resources extraction, primary processing, and manufacturing, to their subsidiaries and contractors in developing economies (e.g., Roberts and Parks, 2007), where environmental regulations and the enforcement thereof are relatively weak (Cole and Neumayer, 2005; Frey, 2006).

Empirical findings support the theory of ecologically unequal exchange. Prior studies employ relational trade measures to analyze the environmental impacts of the vertical flow of exports from developing countries to developed countries. One of such measures is percent of exports to high-income countries (as per World Bank classification) (e.g., Shandra et al., 2009b); the other is “weighted exports flows” or percent of exports to more-developed countries (Jorgenson, 2006). The two measures are highly correlated with each other (Jorgenson, 2012). Studies using the two measures both yield findings consistent with the theory. For developing countries, the vertical flow of exports is found to be associated with increased deforestation (Austin, 2010; Jorgenson, 2006, 2010), organic water pollution (Shandra et al., 2009b), and biodiversity loss (Shandra et al., 2009a). The consequences of these forms of environmental degradation primarily fall upon locales where they occur. Concomitant with the increasing local environmental degradation is a suppression of resource consumption below globally sustainable thresholds, which indicates under-consumption and under-development in developing countries, partly resulting from the vertical flow of exports to higher-income, overconsuming countries (Jorgenson and Clark, 2011; Jorgenson and Rice, 2005; Rice, 2007).

2.2. Ecologically unequal exchange and global climate change

The vertical flow of exports is also associated with increases of anthropogenic carbon dioxide emissions in developing countries (Jorgenson, 2011, 2012). This association is partly the result of developed countries outsourcing carbon intensive manufacturing and resource extraction to developing countries that export the products back to the former (Cole and Neumayer, 2005). Jorgenson (2012) finds that the magnitude of this association has been increasing since 1980, which may be attributed to the “globalization project” (McMichael, 2004) that leads developing countries to undertake manufacturing of goods for export to developed countries (e.g., Jorgenson and Clark, 2009). Through this vertical flow of exports, developed countries displace a part of their production-based carbon emissions to developing countries, while maintaining or even increasing their consumption-based emissions (Knight and Schor, 2014).

The positive association between the vertical flow of exports and carbon emissions for developing nations bears implications for climate change and global climate justice. On one hand, the vertical flow of exports affects the allocation of the responsibility for climate mitigation. To date, international climate negotiation has primarily focused on allocating this responsibility based on current production-based emissions. The vertical flow of exports allows developed countries to displace production-based emissions and thus deflect part of the responsibility for emissions reduction to developing countries that may be assigned more responsibility than what is warranted by their actual carbon footprints. For those developing countries that already lack the financial resources and technological capabilities to pursue a low-carbon economy, reducing carbon emissions could curb their future development.

On the other hand, the vertical flow of exports exacerbates pre-existing inequalities of climate vulnerability and coping capability between developing and developed countries. The distribution of the impacts of climate change is determined by geographical and climatological factors (both global and regional), but is also mediated by each country's ability to cope (Intergovernmental Panel on Climate Change, 2014). Generally speaking, developing countries lacking adequate infrastructure, financial resources, and technological capabilities are more vulnerable to the impacts of climate change, even though they are among the least responsible for causing it (Intergovernmental Panel on Climate Change, 2014; Roberts and Parks, 2007). In contrast, wealthy, developed countries with high levels of historical cumulative emissions and coping capability are primarily responsible for causing climate change but are less vulnerable to its impacts (Roberts and Parks, 2007). These developed countries acquire substantial economic benefits from the vertical flow of exports, which gives them even more resources for climate adaptation. Conversely, this trade flow suppresses the overall development in developing countries, and thus undermines their capability to cope with climate change. Therefore, the vertical flow of exports puts developing countries in a doubly precarious position with both future development and climate vulnerability at stake, and exacerbates pre-existing climate injustice.

2.3. Variations of ecologically unequal exchange during economic recessions: the case of carbon dioxide emissions

Increasing evidence shows that developed countries are in a period of slow growth and frequent recessions (e.g., Gordon, 2012; Piketty, 2014). On one hand, existing research on the implications of recessions for climate change mostly focuses on the changes of domestic factors, including production-based carbon emissions, carbon intensity, policies, business and consumer behavioral changes, and public opinion. Production-based carbon emissions and carbon intensity decline during recessions (Peters et al., 2012). In the case of the United States, several studies attribute such declines to the shift in business and consumer behaviors to adopt more energy-conscious practices (e.g., scrap equipment with lower energy efficiency, reduce consumption of certain energy-intensive goods) (Shahiduzzaman and Layton, 2015; Sheldon, 2017). These shifts can be reinforced and retained during and after recessions by proper governmental stimulus packages, and thus make recessions an opportunity for pursuing a low-carbon economy (Butcher and Stilwell, 2009; Obani and Gupta, 2016). However, studies also find that recessions lower the prominence of climate change in political and public discourse, and that the pursuit of a low-carbon economy is likely hindered by the priority to restore economic growth and by the unfavorable business climate for new investment in the green technology sector (Geels, 2013; Obani and Gupta, 2016; Schor, 2014).

On the other hand, the transnational implications of recessions on climate change are understudied, particularly through their

impacts on the structure of international trade and the ecologically unequal exchange processes. Recessions may affect trade structure because investment and consumption demands in developed countries diminish during recessions, which affects the volume and composition of imports⁵ (Zimmermann, 1997). In addition, the impacts of recessions on the political and public discourses of climate change may affect policy, business, and consumer decisions that in turn affect investment and consumption in different economic sectors to various degrees, which also alters the composition of imports. These changes in the structure of trade likely affect the process of ecologically unequal exchange as well as the amount and proportion of carbon dioxide emissions that are displaced from developed countries to developing countries. Investigating the variations of ecologically unequal exchange can help reveal the extent to which emissions reductions in developed countries during recessions are due to increasing displacement of emissions, as opposed to a genuine pursuit of a low-carbon economy. This investigation contributes to the existing debate on the implications of recessions for climate change, in a period when recessions become an increasingly important feature in the economic pattern in developed countries.

2.4. A country-specific analysis of the United States

Existing research has not provided an adequate empirical analysis of how the environmental impacts of ecologically unequal exchange vary during recessions. This gap may be partly due to a limitation of the conventional approach that studies unequal exchanges between developed countries and developing countries as two groups (e.g., Jorgenson, 2012; Rice, 2007). Research using this approach yields generalizable findings on how the structure of global trade affects the domestic environmental conditions of countries in different positions within the world economy, and constitute the core of empirical analyses on ecologically unequal exchange. Despite its utility, the conventional approach is not well equipped to analyze the variation of ecologically unequal exchange during recessions relative to non-recession periods. This is because for different countries within the same country group (e.g., developed countries), recessions to some extent occur in different forms and magnitudes, often at different times, and may affect unequal exchange processes differently.

As a modest attempt to overcome the limitation of the conventional approach, I propose a country-specific approach that investigates ecologically unequal exchange between a single highly-developed country and its less-developed trade partners. This approach allows researchers to analyze how ecologically unequal exchange varies when recessions occur in this highly-developed country, and assess the degree to which this country displaces its carbon emissions to developing countries, especially during recessions.

The highly-developed country I focus on in this study is the United States. It is the largest importer in the world (United Nations, 2015), one of the largest emitters in terms of total consumption-based carbon dioxide emissions (Davis and Caldeira, 2010), and it experienced two economic recessions in the past two decades (U.S. National Bureau of Economic Research, 2010). Several studies point to a strong possibility that the vertical flow of exports to the United States affect the carbon emissions in developing countries. Stretesky and Lynch (2009) find that exports to the US in monetary value are positively associated with per capita carbon emissions of exporting countries, controlling for GDP, total exports, and other relevant factors. Prell and Feng (2016) find that when developing countries undertake commodity production for export to the US, they gain a larger share of carbon emissions relative to economic value added.

Existing research also finds that economic recessions may have different effects on carbon emissions in the United States and in the rest of the world. Studies using cross-national data and U.S. national data yield different findings on how fast emissions change during economic expansions versus recessions, and on the changes in carbon intensity, even though both find that total carbon emissions increase during economic expansions and decrease during recessions (e.g., Doda, 2014; Heutel, 2012). York's (2012) cross-national analysis shows that from 1960 to 2008, for an average country, the growth rate of production-based per capita carbon emissions during economic expansions is higher than its reduction rate during recessions. Focusing on the recent 2008 global financial crisis, Peters et al. (2012) document a post-crisis growth rate of global total carbon emissions that is more than quadruple of the reduction rate during the crisis. Peters and colleagues also find the trend of decreasing global carbon intensity slowed down during the crisis and the intensity even increased in the year after. In contrast, Shahiduzzaman and Layton (2015) focus on the United States and find that from 1973 to 2013 the growth rates of both total and per capita production-based carbon emissions during economic expansions are lower than their reduction rates during recessions. In addition, they find that while the carbon intensity of the U.S. economy has been gradually decreasing since 1973, it decreases during recessions are on average twice as fast as during economic expansions. This is primarily driven by the energy usage of industrial sector falling more drastically with per unit change of GDP during recessions than it increasing during economic expansions (Sheldon, 2017).

The different findings of studies using two types of data suggest that certain factors facilitate emissions reduction in the United States during recessions and restrain emissions growth after recessions; some other factors inhibit emissions reduction in other countries during recessions and aggravate emissions growth after recessions. The two sets of factors might be related or overlapping. If the structure of trade between the United States and developing countries becomes more ecologically unequal during recessions, it could be a factor that contributes to the different effects of recessions on carbon emissions in the United States relative to the rest of

⁵ Investment is directly associated with the imports of capital goods (i.e. tangible assets used to produce other goods and services), while consumption is directly associated with the imports of consumer goods (Baxter, 1995; Zimmermann, 1997). For most developed countries, investment declines more than consumption during recessions but consumption is associated with a larger proportion of imports than investment (Backus et al., 1995; Zimmermann, 1997), hence both can have sizable impacts on imports. The share of capital goods in imports may drop during recessions because investment declines more than consumption.

the world: during recessions, a larger-than-usual proportion of carbon emissions in the United States is displaced to developing countries that undertake the carbon intensive production for the US; and the displacement remains after recessions. Thus, in the subsequent analyses, I examine (1) the association between carbon dioxide emissions in developing countries and the vertical flow of exports to the United States; and (2) if and how this association changes before, during, and after recent U.S. recessions.

3. Data and methods

3.1. Data

I analyze a balanced cross-sectional time-series dataset comprised of 759 annual observations on 69 nations from 2000 to 2010. I obtained data from the [World Bank \(2015\)](#) World Development Indicator database and the [United Nations \(2015\)](#) Commodity Trade Statistics Database. 97 nations have data available on all dependent and independent variables for the whole 11-year period of investigation. Among these 97 nations, 28 are members of the Organization of Economic Cooperation and Development (OECD) and are also classified by the [World Bank \(2015\)](#) as high-income economies with a Gross National Income (GNI) per capita of \$12,736 or higher in the year 2014. I consider these 28 nations to be developed nations, and thus exclude them from the sample.⁶ I include the remaining 69 developing nations (listed in [Appendix A](#)) in the analysis. The aggregate exports from these nations to the United States account for more than 80% of the exports from all low- and middle-income economies to the United States.⁷

I chose to analyze an 11-year period from 2000 to 2010 because of the timing of recent U.S. economic recessions and data availability. According to the “business cycle dating” data from the U.S. National Bureau of Economic Research (NBER) (2010), two recessions⁸ that occurred in the U.S. in the last two decades were from March 2001 to November 2001, and from December 2007 to June 2009. I converted the business cycle dates into calendar-year form to be consistent with the format of other variables: I designated the years with 6 months or more in recession periods, namely years 2001, 2008, and 2009, as recession years in the United States. I decided to focus on the period from years 2000–2010 so that the years immediately before and after the recessions can be included in the analysis, allowing for a better comparison between recession and non-recession periods. Years before 2000 or after 2010 are excluded due to limited data availability.⁹

3.2. Dependent variable

The dependent variable is annual carbon dioxide emissions per capita measured in metric tons, as obtained from the [World Bank \(2015\)](#) World Development Indicators database. This measure includes emissions generated through the combustion of fossil fuels and the manufacture of cement, but excludes the emissions generated by land use change or by bunker fuels used in international shipping.

3.3. Key independent variables

A key independent variable is the vertical flow of exports to the United States. I operationalize it as merchandise exports to the United States as proportion of total merchandise exports. For each of the 759 country-years in the sample, I obtained data from the United Nations (2015) Commodity Trade Statistics Database on the total value of merchandise exported to the US and the total value exported to the world. I then divided the former by the latter to calculate exports to the US as proportion of total exports. This operationalization, taking into account the structure of the exports flow and the characteristics of the receiving nation (in this case the United States), is theoretically appropriate (see [Jorgenson, 2006](#)) and consistent with prior empirical research on ecologically unequal exchange (e.g., [Jorgenson, 2012](#); [Jorgenson and Clark, 2011](#)).

Time is the independent variable that designates recession years in the analysis. I include one dummy variable for each year from 2001 to 2010. The reference category is year 2000. As noted below, these are also analogous to temporal fixed effects.

⁶ Previous studies (e.g., [Jorgenson, 2012](#)) considered all high-income economies to be developed nations (or “core” nations). I elected to use a more restrictive categorization of developed nations because I analyzed the vertical flow of exports to the United States, one of the most developed and powerful nations in the world. Most nations are less developed and less powerful than the United States. Thus, in this study I only counted nations that have both a high-income status and an OECD membership as developed nations. OECD members include the most developed nations in the world. With less than one fifth of global population, 35 OECD member nations collectively account for 63 percent of GDP and 75 percent of trade in the global economy ([United States Mission to the Organization for Economic Cooperation and Development n.d](#)). In unreported analyses I used a different categorization of developed nations (or core nations) by [Chase-Dunn et al. \(2000\)](#) and obtained similar results.

⁷ Data on merchandise imports from all low- and middle-income economies to the United States was obtained from the [World Bank \(2015\)](#) World Development Indicators database.

⁸ [U.S. National Bureau of Economic Research \(2010\)](#) defines a recession as “a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales”.

⁹ Data availability on main variables prevents me from including more years in the analyses. For example, if I include years 1999 and 2011 in the analysis, 14 countries would be excluded and the sample size would drop from 69 to 55. Unreported two-sample t-tests show that these 14 countries are different from the other developing countries in the sample on 3 variables (i.e. exports as % GDP, urban population as % total population, and manufacturing value added as % GDP), which means their exclusion may introduce bias to the analyses. Thus, I decided to drop years 1999 and 2011 and include these 14 countries in the sample.

3.4. Control variables

I include control variables used in previous studies on ecologically unequal exchange (e.g., Rice, 2007). Gross domestic product (GDP) per capita (in constant 2005 US dollars) is included to control for countries' level of economic development. Previous studies (Jorgenson and Clark, 2012; Knight and Schor, 2014; Longhofer and Jorgenson, 2017) consistently find that GDP per capita is positively associated with carbon emissions per capita.

Urban population as percent of total population is included to control for the level of urbanization. Prior research (e.g., Jorgenson et al., 2014) shows that urban population is an important predictor of carbon emissions per capita, independent of the effect of GDP.

Exports as percent of GDP is included to control for the extent to which a country's economy is integrated into the global economy, which is shown to be positively associated with carbon emissions, especially for developing countries (Jorgenson and Clark, 2012; Roberts and Parks, 2007). Manufacturing value added as percent of GDP is included to control for the domestic economic structure of a country. Data for all control variables were obtained from the World Bank (2015) World Development Indicators database.

3.5. Analytic strategy

I estimated time-series cross-sectional Prais-Winsten (PW) regression models with panel-corrected standard errors (PCSEs) and two-way fixed effects using Stata software. PCSE was employed because Beck and Katz (1995) argue that for panel datasets that do not have many more time points than panels, analysis using generalized least squares techniques may result in extreme overconfidence. I elected to correct for first-order autocorrelation because diagnostic tests failed to reject the null hypothesis of no autocorrelation. To minimize skewness, all continuous variables were transformed using natural logarithm before regression. Two-tailed tests of statistical significance were conducted.

I include two-way fixed effects by including in the models dummy variables for each country and each year: the former controls for unobserved heterogeneity that is unique to each country and consistent through time; the latter controls for unobserved heterogeneity that is unique to each year and invariant for all countries. The general model is specified as follows:

$$y_{it} = \beta x_{it} + u_i + w_t + e_{it}$$

Subscripts i and t represent country and year respectively, and y_{it} is the outcome variable for country i at year t ; βx_{it} is the vector of coefficients for time-varying predictor variables; u_i is the country-specific intercept for country i ; w_t is the year-specific intercept for year t ; e_{it} is the unique residual for country i at year t .

I estimated 3 baseline models to examine whether the vertical flow of exports to the US is associated with increases in carbon dioxide emissions in developing countries. Model 1 includes proportion of exports to the US and GDP per capita. In Model 2, I add exports (% GDP) and urban population (% total population). Model 3 includes all predictors in Model 2 plus manufacturing value added (% GDP). All 3 models include unreported country-specific and year-specific intercepts. Since all continuous variables were transformed with natural logarithms, the regression coefficients are elasticity coefficients that can be interpreted as the percentage change of the outcome associated with a 1-percent increase of a predictor variable, holding other predictors constant.

Next I estimated 3 additional models to examine if and how the association between vertical flow of exports to the US and carbon emissions varies before, during, and after recent US recessions. These 3 models have the same parameterization as the 3 baseline models, respectively, plus a series of interactions between yearly dummy variables and proportion of exports to the US. The reported coefficient for proportion of exports to the US (i.e. the main effect) is its estimated effect in year 2000, the reference category. For each year from 2001 to 2010, the coefficient for the interaction term, if statistically significant, is the difference in the estimated effect between this year and year 2000. I also conducted post-estimation Wald tests to examine if the coefficients for the interaction terms are different during recession years than non-recession years, and if the sum of the coefficients for the main effect and each interaction is larger than zero.

Relevant diagnostics suggest that Belize and St. Kitts and Nevis are overly-influential cases that affect the values and significance levels of regression coefficients. However, the exclusion of either or both countries brings only minimal changes to the trend of the yearly estimated effect of exports to the US, and to the differentials between the effects in different years, and therefore does not affect the overall results of the analyses. Hence, I elected to keep Belize and St. Kitts and Nevis in the sample.

Table 1 presents the summary statistics and bivariate correlations of the 6 non-dummy variables. Summary statistics were calculated using raw data. Correlations were calculated using data transformed with natural logarithm. In the bivariate context, proportion of exports to the US is positively, though weakly, associated with carbon dioxide emissions per capita.

Table 1
Summary Statistics and Bivariate Correlations (*p < .05).

	Variable	N	Mean	SD	Min	Max	1	2	3	4	5
1	CO ₂ emissions per capita	759	3.109	4.248	.0194	38.34					
2	Proportion of exports to the US	759	.166	.198	.0002	.919	.147*				
3	GDP per capita	759	5175	6807	134.8	38689	.791*	.283*			
4	Exports % GDP	759	42.73	33.30	4.686	230.3	.537*	.086*	.556*		
5	Urban pop. % total pop.	759	52.95	23.38	8.246	100	.443*	.012	.654*	.383*	
6	Manufacturing value added % GDP	759	14.69	6.921	.841	35.63	-.004	.025	-.166*	-.010	.123*

Table 2

Unstandardized coefficients for the regression of per capita carbon dioxide emissions, 2000–2010 on proportion of exports to the United States and selected independent variables: two-way fixed effects PW regression model estimates with PCSE and an AR(1) correction for 69 developing countries.

	Model 1	Model 2	Model 3
Proportion of exports to the US	0.295** (0.093)	0.290** (0.095)	0.243** (0.092)
GDP per capita	0.168** (0.052)	0.164** (0.052)	0.187*** (0.053)
Exports % of GDP		− 0.037 (0.025)	− 0.044 (0.024)
Urban pop. % total pop.		0.365*** (0.087)	0.273** (0.105)
Manufacturing value added % GDP			0.124** (0.038)
N	759	759	759
R-squared	0.967	0.967	0.965
Number of Countries	69	69	69
Rho	.529	.525	.559

Notes: all continuous variables were transformed with natural logarithm before regression; all models include unreported year-specific and country-specific intercepts; standard errors in parentheses; unstandardized coefficients flagged for statistical significance.

*p < .05, **p < .01, ***p < .001 (two-tailed tests).

4. Results and discussion

Table 2 reports the findings for 3 baseline models. The estimated effect of proportion of exports to the US is positive and significant in all 3 models, suggesting that overall from years 2000–2010, increases in the vertical flow of exports to the US are positively associated with increases in per capita carbon dioxide emissions in developing countries. Total exports (% GDP) is not associated with per capita carbon emissions, likely because its effect is partially accounted for by proportion of exports to the US. GDP per capita, urban population (% total population), and manufacturing value added (% GDP) are all positively associated with per capita carbon emissions, which is consistent with previous studies. Next, I examine if this association varies before, during, and after recent economic recessions in the US.

Table 3 reports the findings for Models 4 through 6, where I introduce the interactions between proportion of exports to the US and yearly dummy variables from 2001 to 2010. The findings for the 3 models are substantially similar. According to Model 6 (the full model), the coefficients for proportion of exports to the US (i.e. the main effect) and its interactions with years 2001, 2009, and 2010 are positive and statistically significant; the coefficient for its interaction with year 2008 is negative and statistically significant. The coefficients for the interactions with years 2002–2007 are non-significant. As a reminder, the estimated effect of proportion of exports to the US for each year from 2001 to 2010 is the sum of the coefficients for the main effect and the interaction (if the interaction is statistically significant). Models 4 through 6 and unreported Wald tests show that for all but year 2008, proportion of exports to the US is positively associated with per capita carbon emissions¹⁰, which is consistent with the findings for 3 baseline models. The estimated effects in recession years 2001, 2008, and 2009 are different than the estimates in years adjacent to the corresponding recessions ($\alpha = 0.05$).¹¹ In addition, during the period of investigation, the estimated effect reaches the lowest level in year 2008, and the highest level in 2001 and 2010. Fig. 1 presents these estimates based on Model 6. To help contextualize the variations of the estimates, Fig. 1 also presents the annual aggregate volume (billion US \$) of merchandise exports from the 69 developing countries to the US. The estimated effect spiked in recession year 2001 when the volume of exports to the US declined. During the recession in years 2008 and 2009, the estimate dropped initially but then rebounded to the pre-recession level, while the volume of exports peaked in year 2008 and then decreased substantially in 2009. Both the volume of exports to the US and the estimated effect of proportion of exports to the US on carbon emissions reached the highest level in year 2010.

The analyses show that, from years 2000–2010 but with the exception of 2008, the vertical flow of exports from developing countries to the United States is positively associated with per capita carbon emissions in these developing countries, net of the effects of GDP per capita, urban population (% total population), total exports (% GDP), manufacturing value added (% GDP), and both forms of fixed effects. The magnitude of this association varies before, during, and after U.S. recessions.

The findings have several implications. First, the analyses show that the vertical flow of exports as a mechanism of ecologically unequal exchange can exist between one single developed country and its trade partners that are developing countries, which complements previous studies (e.g., Jorgenson, 2012; Jorgenson and Clark, 2009) on ecologically unequal exchange between developed countries and developing countries as two groups. The vertical flow of exports from developing countries to the United States

¹⁰ Although the sum of the coefficients for the main effect and the interaction with year 2008 has a positive value, the Wald test suggests that it is not significantly different from zero.

¹¹ The only exception is that the estimates in years 2009 and 2007 are not significantly different.

Table 3

Unstandardized coefficients for the regression of per capita carbon dioxide emissions, 2000–2010 on interactions between proportion of exports to the United States and time, and selected independent variables: two-way fixed effects PW regression model estimates with PCSE and an AR(1) correction for 69 developing countries.

	Model 4	Model 5	Model 6
Proportion of exports to the US	0.322*** (0.087)	0.303*** (0.090)	0.238** (0.086)
Y2001*Proportion of exports to the US	0.120*** (0.022)	0.119*** (0.022)	0.143*** (0.020)
Y2002*Proportion of exports to the US	0.020 (0.031)	0.020 (0.032)	0.043 (0.030)
Y2003*Proportion of exports to the US	−0.050 (0.031)	−0.043 (0.032)	−0.006 (0.031)
Y2004*Proportion of exports to the US	−0.029 (0.036)	−0.019 (0.038)	0.009 (0.036)
Y2005*Proportion of exports to the US	−0.050 (0.039)	−0.034 (0.040)	−0.005 (0.038)
Y2006*Proportion of exports to the US	−0.037 (0.041)	−0.014 (0.042)	0.001 (0.038)
Y2007*Proportion of exports to the US	−0.005 (0.051)	0.020 (0.053)	0.028 (0.050)
Y2008*Proportion of exports to the US	−0.141** (0.047)	−0.111* (0.049)	−0.097* (0.044)
Y2009*Proportion of exports to the US	0.063 (0.049)	0.096 (0.051)	0.097* (0.048)
Y2010*Proportion of exports to the US	0.166*** (0.042)	0.205*** (0.044)	0.198*** (0.041)
GDP per capita	0.183*** (0.047)	0.182*** (0.047)	0.204*** (0.049)
Exports % GDP		−0.033 (0.024)	−0.039 (0.024)
Urban pop. % total pop.		0.394*** (0.081)	0.302** (0.103)
Manufacturing value added % GDP			0.121** (0.037)
N	759	759	759
R-squared	0.969	0.969	0.967
Number of countries	69	69	69
Rho	.516	.515	.547

Notes: all continuous variables were transformed with natural logarithm before regression; all models include unreported year-specific and country-specific intercepts; standard errors in parentheses; unstandardized coefficients flagged for statistical significance.

*p < .05, **p < .01, ***p < .001 (two-tailed tests).

allows the latter to displace part of its carbon dioxide emissions to the former. This displacement is partly the result of U.S. multinational corporations outsourcing carbon intensive manufacturing and resource extraction to developing countries, combined with the high level of consumption demand in the United States that drives the imports of carbon intensive goods from these countries (Streetsky and Lynch, 2009). Thus, this vertical flow of exports allows the United States to lower its production-based carbon emissions relative to its consumption-based emissions, and to evade part of its responsibility for emissions reduction in international climate negotiations. The evaded responsibility likely falls upon developing countries that undertake carbon-intensive production for the consumption in the United States.

Second, the findings suggest that economic recessions may affect the ecologically unequal exchange of carbon dioxide emissions through the structure of international trade. The structure of trade between the United States and developing countries became more ecologically unequal in years 2001 and 2009, even though the volume of total exports from developing countries to the United States declined. Such variations are likely due to increases in the proportion of carbon-intensive goods¹² in the exports to the United States, which is consistent with the argument that during recessions consumers tend to prefer cheaper imported products (often manufactured in developing countries in a more energy-intensive manner) over “green” products with a price premium (Tienhaara, 2010). Both the proportion and volume of carbon-intensive goods in the exports flow further increased in year 2010, and reached the highest level in the decade. A possible direct cause of such variations is that the outsourcing of carbon-intensive industrial activities to developing countries increased relatively¹³ in years 2001 and 2009, and absolutely in year 2010. Findings of existing studies are consistent with this hypothesis. As noted in the literature review, the energy usage of U.S. industrial sector falls more drastically with per unit change of GDP during recessions than it increases during economic expansions, which is a primary cause of U.S. per capita

¹² i.e. goods with carbon intensive production processes.

¹³ Relative to the total amount of carbon-intensive industrial activities associated with U.S. consumption in that year.

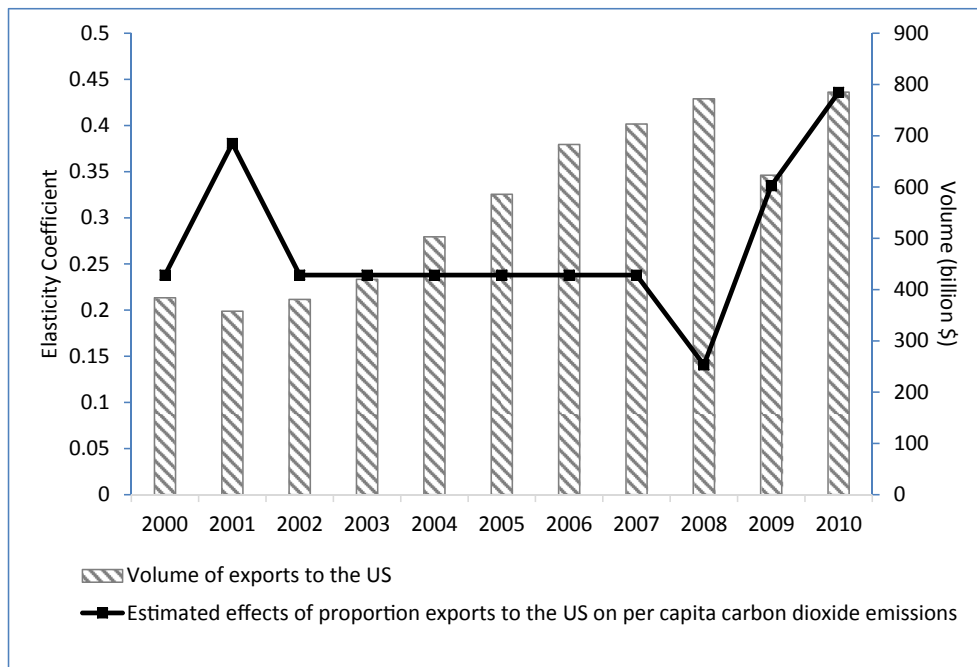


Fig. 1. Estimated effects of proportion of exports to the US on per capita CO₂ emissions for Model 6 and aggregate volume of exports from the 69 developing countries to the US, 2000–2010.

Notes: for the estimated effects of proportion of exports to the US on per capita CO₂ emissions, the data point for year 2000 is the reported coefficient for the main effect of exports to the US. The data points for years 2001 through 2010 are the sum of the coefficients for the main effect and the interaction (treated as 0 if non-significant). The estimated effects for all years but 2008 are significantly larger than 0 (see footnote 10).

carbon emissions decreasing more sharply during recessions than they increasing during economic expansions (Shahiduzzaman and Layton, 2015; Sheldon, 2017). Conversely, for an average country in cross-national analyses, emissions per capita increase more sharply during economic expansions than they decrease during recessions (York, 2012). An increased outsourcing of carbon-intensive industrial activities during recessions partly explains why US-specific studies and cross-national studies have the opposite findings. Increases in the outsourcing can facilitate emissions reduction in the United States during recessions and restrain emissions growth during post-recession recovery, especially in the industrial sector; meanwhile, they can inhibit emissions reduction in developing countries during U.S. recessions¹⁴ and aggravate emissions growth after recessions.

Year 2008, the onset of the Great Recession, is an anomalous year when the vertical flow of exports to the United States was not associated with increases of carbon emissions in developing countries, even though the volume of the exports flow was at a level similar to year 2010. A thorough explanation of this anomaly is beyond the scope of this study. Nevertheless, its occurrence might be because the proportion of less-carbon-intensive goods in the exports flow was higher in 2008 than in other years, which could partly be due to the temporal gap between the time when businesses initially react to the recession (e.g., cancellation of orders) and the time when these reactions materialize in trade flows. The temporal gap may vary for different economic sectors, which affects the composition of the exports flow. A similar alleviation is not observed during the 2001 recession, which may be because it was shallower in depth, shorter in length, and affected fewer regions in the world compared to the 2008 Great Recession¹⁵ (see World Bank, 2010; Kliesen, 2003; Labonte, 2010).

Third, the analyses shed light on the transnational impacts of U.S. economic recessions on carbon dioxide emissions in developing countries, especially in the case of the Great Recession. The heightened “ecological inequality” of the trade structure in years 2009 and 2010 may indicate that while the United States was going through a recession and its aftermath, the economic sectors in developing countries that orient toward exporting to the United States were further entrenched in the production of energy- and carbon-intensive goods. In the year 2009, the impacts of such entrenchment on carbon emissions in developing countries may not be particularly prominent due to the substantial decrease in the volume of exports to the United States. In the year 2010, however, the impacts would be more fully materialized as the volume of exports recovered. Even though specific data is unavailable, year 2010 is arguably the year with the largest amount of U.S. consumption-based carbon emissions emitted in developing countries, compared to other years in the period of investigation. Overall, U.S. recessions are associated with changes in the ecological inequality of the

¹⁴ Some economic studies suggest that the timing of recessions tend to synchronize between countries with strong trade connections (e.g., Clark and Van Wincoop, 2001; Duval et al., 2014). The timing of recessions in some developing countries may overlap with the timing of U.S. recessions.

¹⁵ In addition, the two recessions had different causes and elicited different policy responses.

structure of trade between developing countries and the United States, and thus likely affect the proportion and absolute amount of U.S. consumption-based carbon emissions that are displaced to developing countries. Given that the United States is the largest importer in the world and one of the largest emitters in terms of consumption-based carbon emissions, U.S. economic recessions could change the carbon emissions in many developing countries by non-trivial amounts.

Fourth, the impacts of U.S. recessions on the ecological inequality of the structure of trade need to be considered when assessing the implications of recessions for climate change mitigation in the United States. Consumption and import of goods each accounts for a significant portion of U.S. GDP,¹⁶ and the displaced carbon emissions generated in developing countries during the production of goods to be imported to and consumed in the United States are an important component of U.S. overall consumption-based emissions. Therefore, taking into account the variations of the displaced emissions during recessions, as well as the structure of trade underlying such variations, can help researchers more accurately assess how recessions affect climate change mitigation and contribute to the current debate on this issue.

5. Conclusion

This study investigates if and how the recent U.S. economic recessions affect the ecologically unequal exchange of carbon dioxide emissions between developing countries and the United States. The findings suggest that the vertical flow of exports as a mechanism of ecologically unequal exchange can exist between one single developed country (in this case the United States) and its trade partners that are developing countries. This vertical flow allows the United States to partially displace its carbon emissions to developing countries, and thus evade part of its responsibility for climate mitigation. The findings also highlight that economic recessions in the United States are associated with variations of its ecologically unequal exchange with developing countries. Because of the variations, the amount and proportion of U.S. consumption-based carbon emissions that are displaced to developing countries are likely to change before, during, and after recessions. Such transnational impacts of recessions need to be considered when assessing how economic recessions affect climate change and its mitigation.

This study shows that country-specific analyses can help further the sociological research on ecologically unequal exchange, especially how it is affected by events specific to each country. Future research should investigate if similar findings apply to other developed countries. This study has several limitations. First, I used time dummy variables to count for the differences between recessions and non-recession years. The magnitude and other characteristics of recessions were not taken into account as much as they likely should be. Second, the current study did not investigate the potential effects of recessions that occurred in the developing countries that export to the United States. Third, due to data availability, this study only analyzes the period of 2000 to 2010. Future research should find ways to address these limitations and investigate if the variation of ecologically unequal exchange continues into year 2011 and beyond.

This study calls for further investigation of the underlying reasons why ecologically unequal exchange varies before, during, and after economic recessions. In the case analyzed above, it is noteworthy that the variations only occurred during recessions and years adjacent to the recessions, which is a stark contrast with the 6 years (2002–2007) between the two recessions when the ecological inequality of the structure of trade remained unchanged, at least based on tests of statistical significance. Hence, the variations are likely caused by factors closely related to recessions. Among possible mechanisms are the variations in the volume and composition of goods imported by developed countries during recessions. Recessions are associated with declines of domestic investment and consumption, which lead to declines in total imports and particularly the imports of capital goods (e.g., [De Bock, 2012](#)). However, to better explain the variations in ecologically unequal exchange (including the anomaly that occurred in the year 2008), researchers also need to understand how and why recessions affect the composition of imports in terms of both geographical origins (e.g., developing countries or developed countries) and carbon intensity of goods. This may require (1) an investigation into the changes of the export-oriented sectors in developing countries during recessions that occur in developed countries, including identifying specific carbon intensive industries and commodities that contribute to the observed variations in the ecologically unequal exchange processes; and (2) a quantitative estimation of the variations in the amount of consumption-based emissions that are displaced to developing countries. These inquiries can also help better assess the implications of economic recessions for climate change.

Acknowledgement

The author thanks Andrew K. Jorgenson, Juliet B. Schor, and the anonymous reviewers for helpful comments on earlier drafts of this article. An earlier version was presented at the 2017 Annual Meetings of the American Sociological Association in Montréal, Québec. The author also thanks members of the Boston College Environmental Sociology Workshop for their helpful suggestions on earlier drafts.

¹⁶ For example, in 2010, personal consumption expenditures on goods and imports of goods accounted for, respectively, 22% and 11% of U.S. GDP ([U.S. Bureau of Economic Analysis, 2017](#)).

Appendix

Appendix A Countries Included in the Analyses.

Albania	Egypt	Namibia
Argentina	Ethiopia	Niger
Armenia	Georgia	Nicaragua
Azerbaijan	Hong Kong SAR, China	Oman
Bahamas	Indonesia	Panama
Barbados	India	Peru
Burundi	Jordan	Philippines
Benin	Kazakhstan	Senegal
Bangladesh	Kenya	Singapore
Belarus	Kyrgyz Republic	El Salvador
Belize	Cambodia	Thailand
Bolivia	Latvia	Tonga
Brazil	Lebanon	Tunisia
Botswana	Sri Lanka	Turkey
China	Macao SAR, China	Tanzania
Cote d'Ivoire	Morocco	Trinidad and Tobago
Cameroon	Moldova	Uruguay
Croatia	Mexico	Ukraine
Colombia	Mozambique	St. Vincent and the Grenadines
Costa Rica	Mauritius	St. Kitts and Nevis
Cyprus	Malawi	Vietnam
Dominica	Malaysia	South Africa
Ecuador	Malta	Zambia

References

- Austin, Kelly, 2010. The 'hamburger connection' as ecologically unequal exchange: a cross-national investigation of beef exports and deforestation in less-developed countries. *Rural Sociol.* 75 (2), 270–299.
- Backus, David K., Kehoe, Patrick J., Kydland, Finn E., 1995. International business cycles: theory vs. evidence. In: Cooley, T.F. (Ed.), *Frontiers of Business Cycle Research*. Princeton University Press, Princeton, NJ, pp. 331–356.
- Baxter, Marianne, 1995. International trade and business cycles. In: Grossman, G.M., Rogoff, K. (Eds.), *Handbook of International Economics*, vol. 3. Elsevier, Amsterdam, the Netherlands, pp. 1801–1864.
- Beck, Nathaniel, Katz, Jonathan N., 1995. What to do (and not to do) with time-series cross-section data. *Am. Polit. Sci. Rev.* 89 (3), 634–647.
- Bunker, Stephen G., 1984. Modes of extraction, unequal exchange, and the progressive underdevelopment of an extreme periphery: the Brazilian Amazon, 1600–1980. *Am. J. Sociol.* 89 (5), 1017–1064.
- Butcher, Ben Spies, Stilwell, Frank, 2009. Climate change policy and economic recession. *J. Aust. Polit. Econ.* 63, 108–125.
- Chase-Dunn, Christopher, Kawano, Yukio, Brewer, Benjamin D., 2000. Trade globalization since 1975: waves of integration in the world-system. *Am. Socio. Rev.* 65 (1), 77–95.
- Clark, Todd E., Van Wincoop, Eric, 2001. Borders and business cycles. *J. Int. Econ.* 55 (1), 59–85.
- Cole, Matthew A., Neumayer, Eric, 2005. Environmental policy and the environmental kuznets Curve: can developing countries escape the detrimental consequences of economic growth? In: Dauvergne, P. (Ed.), *Handbook of Global Environmental Politics*. Edward Elgar, Northampton, MA, pp. 298–318.
- Davis, Steven J., Caldeira, Ken, 2010. Consumption-based accounting of CO₂ emissions. *Proc. Natl. Acad. Sci. U.S.A.* 107 (12), 5687–5692.
- De Bock, Reinout, 2012. The composition and cyclical behavior of trade flows in emerging economies. *International Economics* 132, 5–33.
- Doda, Baran, 2014. Evidence on business cycles and CO₂ emissions. *J. Macroecon.* 40, 214–227.
- Duval, R., Cheng, K., Oh, K.H., Saraf, R., Seneviratne, D., 2014. Trade Integration and Business Cycle Synchronization: A Reappraisal with Focus on Asia. *IMF Working Papers*. <https://doi.org/10.5089/9781475522464.001>.
- Frey, R.Scott, 2006. The flow of hazardous exports in the world-system. In: Jorgenson, A.K., Kick, E.L. (Eds.), *Globalization and the Environment*. Brill Academic Press, Leiden, the Netherlands, pp. 133–149.
- Galtung, Johan, 1971. A structural theory of imperialism. *J. Peace Res.* 8 (2), 81–117.
- Geels, Frank W., 2013. The impact of the financial-economic crisis on sustainability transitions: financial investment, governance and public discourse. *Environ. Innovat. Soc. Transit.* 6, 67–95.
- Georgescu-Roegen, Nicholas, 1971. *The Entropy Law and the Economic Process*. Harvard University Press, Cambridge, MA.
- Gordon, Robert J., 2012. Is U.S. Economic Growth Over? *Faltering Innovation Confronts the Six Headwinds* (No. 18315). NBER Working Paper. Cambridge, MA.
- Heutel, Garth, 2012. How should environmental policy respond to business Cycles? Optimal policy under persistent productivity shocks. *Rev. Econ. Dynam.* 15 (2), 244–264.
- Hornborg, Alf, 1998. Towards an ecological theory of unequal exchange: articulating world system theory and ecological economics. *Ecol. Econ.* 25 (1), 127–136.
- Hornborg, Alf, 2009. Zero-sum world: challenges in conceptualizing environmental load displacement and ecologically unequal exchange in the world-system. *Int. J. Comp. Sociol.* 50 (3–4), 237–262.
- Intergovernmental Panel on Climate Change, 2014. *Climate Change 2014: Synthesis Report, Fifth Assessment Report*. Geneva, Switzerland.
- Jorgenson, Andrew K., 2006. Unequal ecological exchange and environmental degradation: a theoretical proposition and cross-national study of deforestation, 1990–2000. *Rural Sociol.* 71 (4), 685–712.
- Jorgenson, Andrew K., 2010. World-economic integration, supply depots, and environmental degradation: a study of ecologically unequal exchange, foreign

- investment dependence, and deforestation in less developed countries. *Crit. Sociol.* 36 (3), 453–477.
- Jorgenson, Andrew K., 2011. Carbon dioxide emissions in central and eastern european nations, 1992–2005: a test of ecologically unequal exchange theory. *Hum. Ecol. Rev.* 18 (2), 105–114.
- Jorgenson, Andrew K., 2012. The Sociology of ecologically unequal exchange and carbon dioxide emissions, 1960–2005. *Soc. Sci. Res.* 41 (2), 242–252.
- Jorgenson, Andrew K., Clark, Brett, 2009. The economy, military, and ecologically unequal exchange relationships in comparative perspective: a panel study of the ecological footprints of nations, 1975–2000. *Soc. Probl.* 56 (4), 621–646.
- Jorgenson, Andrew K., Clark, Brett, 2011. Societies consuming nature: a panel study of the ecological footprints of nations, 1960–2003. *Soc. Sci. Res.* 40 (1), 226–244.
- Jorgenson, Andrew K., Clark, Brett, 2012. Are the economy and the environment Decoupling? A comparative international study, 1960–2005. *Am. J. Sociol.* 118 (1), 1–44.
- Jorgenson, Andrew K., Rice, James, 2005. Structural dynamics of international trade and material consumption: a cross-national study of the ecological footprints of less-developed countries. *J. World Syst. Res.* 11 (1), 57–77.
- Jorgenson, Andrew K., Auerbach, Daniel, Clark, Brett, 2014. The (de-) carbonization of urbanization, 1960–2010. *Climatic Change* 127 (3–4), 561–575.
- Kentor, Jeffrey, Boswell, Terry, 2003. Foreign capital dependence and development: a new direction. *American Sociological Review* 68 (2), 301–313.
- Kliesen, Kevin L., 2003. The 2001 recession: how was it different and what developments may have caused it? *Fed. Reserv. Bank St. Louis Rev.* 85 (5), 23–38.
- Knight, Kyle W., Schor, Juliet B., 2014. Economic growth and climate change: a cross-national analysis of territorial and consumption-based carbon emissions in high-income countries. *Sustainability* 6 (6), 3722–3731.
- Labonte, Marc, 2010. *The 2007–2009 Recession: Similarities to and Differences from the Past.* (Washington, DC).
- Longhofer, Wesley, Jorgenson, Andrew, 2017. Decoupling reconsidered: does world society integration influence the relationship between the environment and economic development? *Soc. Sci. Res.*, vol. 65, 17–29.
- McMichael, Philip, 2004. *Development and Social Change: a Global Perspective*, fifth ed. Sage, Thousand Oaks, CA.
- Obani, Pedi Chiemenia, Gupta, Joyeeta, 2016. The impact of economic recession on climate change: eight trends. *Clim. Dev.* 8 (3), 211–223.
- Peters, Glen P., et al., 2012. Rapid growth in CO₂ emissions after the 2008–2009 global financial crisis. *Nat. Clim. Change* 2 (1), 2–4.
- Petev, Ivaylo D., Pistaferri, Luigi, Saporta-Eksten, Itay, 2011. An analysis of trends, perceptions, and distributional effects in consumption. In: Grusky, D.B., Western, B., Wimer, C. (Eds.), *The Great Recession*. Russell Sage Foundation, New York, pp. 161–195.
- Piketty, Thomas, 2014. *Capital in the Twenty-first Century*. The Belknap Press of Harvard University Press, Cambridge, MA.
- Prell, C., Feng, K., 2016. Unequal carbon exchanges: the environmental and economic impacts of iconic U.S. Consumption items. *J. Ind. Ecol.* 20 (3), 537–546.
- Rice, James, 2007. Ecological unequal exchange: international trade and uneven utilization of environmental space in the world system. *Soc. Forces* 85 (3), 1369–1392.
- Roberts, J. Timmons, Parks, Bradley, 2007. *A Climate of Injustice: Global Inequality, North-South Politics, and Climate Policy*. MIT Press, Cambridge, MA.
- Schor, Juliet B., 2014. Climate discourse and economic downturns: the case of the United States, 2008–2013. *Environ. Innovat. Soc. Transit.* 13, 6–20.
- Shahiduzzaman, Md, Layton, Allan, 2015. Changes in CO₂ emissions over business cycle recessions and expansions in the United States: a decomposition analysis. *Appl. Energy* 150, 25–35.
- Shandra, John M., Leckband, Christopher, McKinney, Laura A., London, Bruce, 2009a. Ecologically unequal exchange, world polity, and biodiversity loss: a cross-national analysis of threatened mammals. *Int. J. Comp. Sociol.* 50 (3–4), 285–310.
- Shandra, John M., Shor, Eran, London, Bruce, 2009b. World polity, unequal ecological exchange, and organic water pollution: a cross-national analysis of developing nations. *Hum. Ecol. Rev.* 16 (1), 53–63.
- Sheldon, Tamara L., 2017. Asymmetric effects of the business cycle on carbon dioxide emissions. *Energy Econ.* 61, 289–297.
- Stretesky, Paul B., Lynch, Michael J., 2009. A cross-national study of the association between per capita carbon dioxide emissions and exports to the United States. *Soc. Sci. Res.* 38 (1), 239–250.
- Tienhaara, Kyla, 2010. A tale of two crises: what the global financial crisis means for the global environmental crisis. *Environmental Policy and Governance* 20 (3), 197–208.
- United Nations, 2015. UNcomtrade: United Nations Commodity Trade Statistics Database. Retrieved December 2, 2015. <http://comtrade.un.org/db/default.aspx>.
- United States Mission to the Organization for Economic Cooperation and Development n.d. What Is the OECD. Retrieved August 20, 2016 (<http://usoecd.usmission.gov/mission/overview.html>).
- U.S. National Bureau of Economic Research, 2010. U.S. Business Cycle Expansions and Contractions. Retrieved November 8, 2015. <http://www.nber.org/cycles.html>.
- U.S. Bureau of Economic Analysis, 2017. BEA National Economic Accounts. Retrieved February 3, 2017. <https://www.bea.gov/national/index.htm>.
- Wall, G., 1986. *Exergy: A Useful Concept*. Thesis. Chalmers University of Technology, Gothenburg.
- World Bank, 2010. *Global Economic Prospects 2010: Crisis, Finance, and Growth*. (Washington, DC).
- World Bank, 2015. *World Development Indicators*. Retrieved November 6, 2015. <http://data.worldbank.org/data-catalog/world-development-indicators>.
- York, Richard, 2012. Asymmetric effects of economic growth and decline on CO₂ emissions. *Nat. Clim. Change* 2 (11), 762–764.
- Zimmermann, C., 1997. *International Trade over the Business Cycle: Stylized Facts and Remaining Puzzles* (No. 37). CREFE Working Papers. Montréal, Quebec.